

## CASE SERIES

## A SIX-WEEK SUPERVISED EXERCISE AND EDUCATIONAL INTERVENTION AFTER TOTAL HIP ARTHROPLASTY: A CASE SERIES

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## ABSTRACT

**Background and Purpose:** Most rehabilitation interventions after total hip arthroplasty (THA) are not designed to return patients to high-levels of physical activity and, thus, low levels of physical activity and residual weakness are common. The purpose of this case series was to describe the feasibility and preliminary efficacy of an exercise and education intervention for patients after THA who have already completed formal outpatient physical therapy.

**Study Design:** Case series

**Case Description:** Two participants underwent unilateral THA seven (case A) or eight (case B) months prior to the intervention. Individuals participated in 18 treatment sessions that included progressive aerobic and strengthening exercises and meetings with a health coach. Change in function, strength, and self-reported physical activity were measured. Outcomes 12 months after surgery were compared to a historical cohort of patients after THA.

**Outcome:** There were no adverse events during the intervention. At the end of the intervention, hip and knee strength on the surgical side increased approximately 30% compared to baseline in both cases. Activity level, and recreational performance, including walking up stairs and hiking uphill (case A), and running and golfing (case B), improved by the end of the intervention. Most changes were maintained at follow-up, although hip strength for case B decreased 27% after discharge from the intervention. Outcomes for both cases exceeded historical averages for patients 12 months after THA, with the exception of strength in case B.

**Discussion:** The exercise intervention was well tolerated and without negative effects in two participants. Both participants increased their ability to complete demanding recreational and sports-related activities, physical activity, and demonstrated improved hip abductor and knee extensor strength. Further research is needed to evaluate the implementation and effectiveness of similar interventions after THA.

**Level of Evidence:** Level 4

**Key words:** Aerobic exercises, activity level, lower limb strengthening, total hip arthroplasty

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## BACKGROUND

The incidence of total hip arthroplasty (THA) has increased over the past 10 years.<sup>1,2</sup> Although this procedure improves pain and patient-reported outcomes,<sup>3</sup> many individuals after THA exhibit impairments and functional limitations when compared to older adults without joint pathology.<sup>4</sup> This is particularly concerning as the demographic of patients who elect to undergo THA has been getting progressively younger.<sup>5</sup> Younger individuals may have higher functional and participation goals compared to older adults, which may require modification of current rehabilitation protocols to improve the likelihood of returning to recreational and vocational activities after THA.

Physical inactivity is one of the major public health problems of the 21<sup>st</sup> century.<sup>6</sup> The health benefits obtained from physical activity surpass outcomes from pharmacological interventions by reducing the risk of death to a greater extent than medications.<sup>7</sup> Identifying strategies to improve physical activity is critical for patients' health and well-being,<sup>8</sup> as active lifestyle and participation in exercise improves health of individuals with many common chronic conditions.<sup>9</sup>

Joint pain is a barrier to physical activity and exercise before arthroplasty surgery.<sup>10</sup> Most of the patients with lower extremity osteoarthritis do not meet the recommended level of physical activity.<sup>11,12</sup> Current physical therapy protocols post THA focus on resolving impairments and improving independent mobility. Despite the resolution of pain and improved perception of abilities,<sup>13-15</sup> negligible improvements in physical activity have been measured up to one year following THA,<sup>12,16</sup> suggesting that most patients do not adopt an active lifestyle. After THA, physical activity may not change without targeted intervention<sup>16</sup> and evidence on rehabilitation protocols to improve physical activity and exercise participation is lacking.<sup>16</sup>

Patients have to follow post-operative surgical precautions to allow tissue healing and prevent the risk of dislocation up to 6 to 12 weeks after THA.<sup>17,18</sup> These precautions may limit progressively increasing or intense strengthening and functional training. Furthermore, although patients are typically not enrolled

in formal interventions after the third post-surgical month, functional performance continues to improve, and reaches a plateau 12 months after surgery.<sup>4,19</sup> Therefore, targeting impairments that are related to functional performance, such as residual weakness and aerobic capacity, may optimize outcomes for patients after THA. Considering the current evidence, an intervention was developed that included aerobic and strengthening exercises, as well as educational components that targeted behavioral changes. This intervention was designed for patients at least three months following THA, who were already discharged from physical therapy. The goal of this intervention was to increase lower limb strength, increase physical activity, and improve functional outcomes after THA. The purpose of this case series was to describe the feasibility and preliminary efficacy of this exercise and education intervention for patients after THA who have already completed formal outpatient physical therapy. Outcomes of the individuals who participated in this intervention were also compared to a historical cohort of subjects who underwent THA, but did not receive any targeted exercise and behavioral intervention after THA.

## CASE DESCRIPTIONS

Participants were recruited from a larger longitudinal study. To be included in the parent study, participants had to be between the ages 40 and 70 and be scheduled for a unilateral THA. Participants were excluded from the parent study if they had: 1) neurological, vascular or other lower extremity musculoskeletal conditions that affected gait or functional performance, 2) uncontrolled hypertension, 3) self-reported lack of sensation in the lower extremities, and 4) history of cancer in the lower extremity. Participants included in this case series were recruited between three and nine months after THA. Because the intervention for the case series involved cardiovascular exercise, the participants met all the criteria above, but also did not have: 1) history of chest pain, heart attack, or heart failure, 2) complications after THA, and 3) previous THA or a planned future contralateral THA. The testing and intervention procedures were approved by the Institution review board and participants gave informed consent before starting any component of the protocol. Both cases underwent anterolateral THA by the same surgeon.

### Case A

A 62-year-old female was recruited seven months after THA. She underwent four acute care physical therapy sessions while hospitalized. After discharge, she was enrolled in 12 outpatient physical therapy sessions. She sustained a fall four months after the surgery and fractured her wrist, but her past medical history was otherwise non-significant. At the time of enrollment, the wrist cast was removed and she was cleared to return to activity.

### Case B

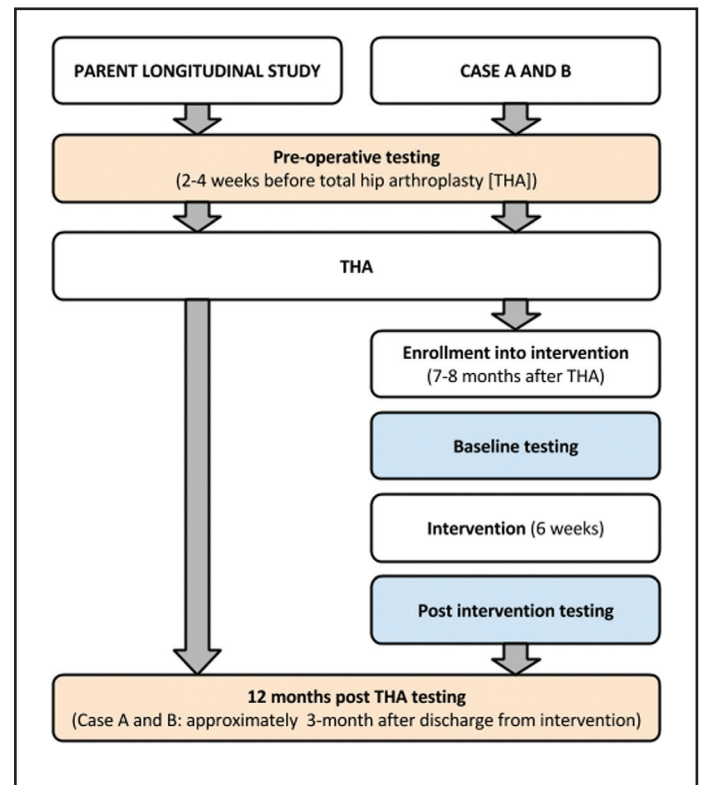
A 62-year-old male was recruited eight months after THA. He underwent three acute care physical therapy sessions while hospitalized. After discharge, he was enrolled in five home and 12 outpatient physical therapy sessions. The past medical history was non-significant, although the baseline graded exercises testing session was terminated due to presence of ectopic heart beats in the resting electrocardiogram. After he obtained clearance from his cardiologist, he was able to complete the graded exercise testing and was enrolled in the intervention.

## HISTORICAL LONGITUDINAL COHORT

Thirty-two participants enrolled in the longitudinal parent study were included as historical cohort (THA approach: 11 anterolateral [34%], one direct lateral [3%], and 20 posterior [63%]). Physical therapy treatment after THA was not standardized and participants attended physical therapy as prescribed by their treating orthopaedic surgeon. In this cohort, 18 participants underwent a combination of home and outpatient physical therapy (56%); seven underwent only outpatient physical therapy (22%); and four underwent only home physical therapy (13%). Information regarding post-THA physical therapy was not available for three participants (9%).

## PROCEDURE

Participants in the longitudinal parent study attended two testing sessions (2-4 weeks before THA and 12 months after THA), while participants in the case series attended four testing sessions (2-4 weeks before THA, immediately prior to the intervention, at the end of the intervention, and 12 months after THA, Figure 1).



**Figure 1.** Study time line for participants enrolled in the longitudinal study and the current case series. Orange shaded rectangles represent evaluation timepoints that both groups attended. Blue shaded rectangles represent evaluation timepoints that only participants included in the case series attended.

## OUTCOME MEASURES – ALL PARTICIPANTS

Participants completed the Hip Outcome Survey (HOS),<sup>20</sup> which includes six questions that ask patients to rate the impact of common symptoms on daily activities, and seven questions where patients are asked to rate their functional limitations during activities. Maximal score is 100%, which represents full hip function.

Hip abductor muscle strength was measured with the participant positioned in side lying with a non-elastic strap positioned around their distal thigh at all of the testing time points.<sup>21</sup> A hand-held dynamometer (Model 01165; Lafayette Instrument, Lafayette, IN) was positioned proximal to the lateral femoral condyles and its position was held constant between trials to avoid changes in the resistance moment arm. Subjects were asked to push into the strap (abduct their hip) as hard as possible. The maximal trial from three attempts was used as the maximal isometric contraction. This method has been shown to be valid and reliable in older adults.<sup>21</sup> Strength values were recorded in Newtons and normalized to body mass (Kg).

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Maximal voluntary isometric strength for the quadriceps muscle was measured using an electromechanical dynamometer (Kin-Com, Chattex Inc., Chattanooga, TN, USA).<sup>22</sup> Participants were seated with the knee at 75° of flexion. After warm up contractions, three maximal contractions were performed with one minute of rest between repetitions. Force data were recorded in Newtons using a force transducer located at the distal anterior tibia two centimeters proximal to the lateral malleolus and were normalized to body mass (Kg).

Participants performed the Timed Up and Go (TUG), the timed Stair Climbing Test (SCT), and the Six-Minute Walk tests (6MW). For the TUG, participants stood up from a chair without using the armrests, moved as fast as possible for three meters, turned around, and returned back to sit on the chair.<sup>23</sup> For the SCT, participants ascended and descended a set of 12 steps (15cm rise, 20cm run) “as fast as possible while still being safe”. If needed, participants were allowed to use one hand-rail, but were not allowed to skip steps.<sup>24</sup> For the 6MW, participants walked as far as they could for six minutes along a 115 m square hallway. Participants were allowed to rest, if needed, but time was not stopped during rest.<sup>25</sup>

### **OUTCOME MEASURES – CASE SERIES ONLY**

Participants in the case series completed the Fatigue Severity Score (FSS), the International Physical Activity Questionnaire short form (I-PAQ), and Patient Specific Functional Scale (PSFS). The FSS<sup>26</sup> is a nine item questionnaire that measure the severity of fatigue and its effect on participants activity and lifestyle. The maximum score is 63, which indicates the highest level of fatigue. The I-PAQ-short version<sup>27</sup> asks participants to report the amount of days and time over the previous week that they spent sitting, walking, and doing vigorous and moderate activities. The metabolic equivalent (MET) energy expenditure over the week was calculated based on the participants' answers. The PSFS<sup>28</sup> asks patients to identify activities that are unable to complete due to their current injury. Participants are then asked to rate their level of impairment from “0, unable to perform” to “10, able to perform activity at the same level as before injury”. The minimum detectable change at the 90% confidence interval for a single activity is 3-points.<sup>28</sup>

Leg loading during sit to stand was measured by asking participants to stand up from a piano stool with



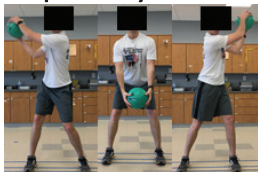
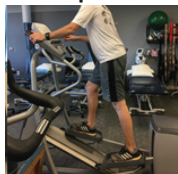


the arm crossed on their chest.<sup>29</sup> Two force plates (Bertec Corp, Worthington, Ohio, USA) were used to collect ground reaction forces from the surgical and non-surgical leg. Signal was acquired at 1080Hz, and filtered with a low-pass Butterworth filter (cut-off frequency 40Hz). Symmetry index was obtained by dividing the peak vertical ground reaction force of the surgical leg by the peak of the non-surgical leg (100% represents perfect symmetry).

### **INTERVENTION**

The two case report subjects underwent a medical screening and a graded exercise stress test prior to enrollment in the intervention. If no absolute or relative risks were indicated in the initial health history questionnaire, participants underwent resting electrocardiogram and blood pressure testing. Once cleared, participants completed a graded exercise testing according to the modified Bruce protocol.<sup>30</sup> A cardiologist reviewed the results of the graded exercise to determine eligibility for the exercise intervention.

The exercise intervention included 18 supervised sessions over the course of six-weeks. Each session lasted one-hour and included two 15-minute aerobic components, one 20-minute strengthening component, and 10 total minutes for recovery and transfer between exercises. This exercise construct has been successfully and safely implemented in the IDEA trial.<sup>31</sup> Methods of aerobic and resistive weight training were tailored to each participant's baseline status and goals, as described in the PSFS. With regard to the PSFS, Case A desired to improve walking (fast speed and hiking uphill) and stair climbing. Therefore, treadmill with change in inclination and elliptical machine were used as preferred methods for aerobic training. Strengthening exercises included stepping activity (progressed with the addition of weight) and balance exercises on different surface to prepare walking on uneven surfaces. Case B desired to improve running and golfing. During treadmill training, speed increase was used to reach the targeted heart rate. After three weeks of conventional strength exercises (hip abductors set, shuffle gait, leg press, etc.), golf specific exercises were added (golf swing movements with exercise balls of differing weights). Case B performed simulated golf putting on different destabilizing surfaces and rocker boards. During these exercises, he was required to putt a golf ball into a cup to add an additional layer of complexity (Table 1).

**Table 1.** Exercise intervention description according to the Consensus on Exercise Reporting

		EXERCISE INTERVENTION		
	Item #	Aerobic component	Strengthening component	
Materials/ Equipment	1	Treadmill, stationary bicycle, and elliptical. Commercially available heart rate monitor	Weight machines, thera-band, destabilizing devices, etc.	
Provider	2	Licensed physical therapist		
Delivery	3	Individual session		
	4	Supervised		
	5	Measurement taken by the physical therapist during each session		
	6	Motivation and feedback provided by the physical therapist as needed		
	7	Progressed to maintain target heart rate	Ability to perform 3 set of 10 minimal pain (1/10) and discomfort	
	8*			<b>Lower Extremity Strength</b> 
			<b>Treadmill</b> 	<b>Sport specific Dynamic ex Golf</b> 
			<b>Elliptical</b> 	<b>Dynamic Balance Sport Specific ex. Golf</b> 
				<b>Core stability/dynamic</b> 
	9	No home exercise program		
	10	Behavioral component: meeting and phone call with a health coach		
	11	No adverse effect occurred during exercise		
Location	12	Outpatient physical therapy clinic		
Dosage	13	<b>Component duration:</b> 15 minute <b>Component per session:</b> 2 <b>Intensity:</b> 65-80% predicted heart rate max	<b>Component duration:</b> 20 minutes. <b>Exercise per session:</b> between 3 and 6. <b>Sets:</b> between 2 and 3. <b>Repetition:</b> between 5 and 10. <b>Intensity:</b> tailored to individual	
Tailoring	14	Tailored to individual		
	15	65% Heart rate max	Starting level was based on patient level of fitness and reported symptoms	
Planned, Actual	16	Exercise intervention was delivered as planned		

\*Multiple exercises were used during the strengthening component. Pictures display only some of the exercises performed.

For aerobic exercises, a heart rate monitor was used to confirm that exercise intensity ranged between 65–80% of the predicted heart rate maximum. The starting intensity and progression of the intervention components were dependent on the individual's tolerance to each exercise session and according to a pain-monitoring model.<sup>32</sup> Low back and lower extremity joint pain was recorded before each exercise session (verbal analog scale: 0, no pain; 10, worst pain imaginable), and appearance of severe pain, swelling, and tenderness after the previous exercise session (yes/no question). At the end of the session, participants were asked to rate their current level of pain in the low back and lower extremity joints. These data were then used for the feasibility analysis.

Participants met with a health coach during the first week of the exercise intervention. This meeting focused on awareness of healthy eating habits, identifying barriers to participation, setting personal health goals, and identifying strategies to stay engaged in the program. These behavioral intervention components have been shown to change sedentary behaviors in older adults.<sup>33</sup> The health coach followed-up weekly through phone calls to review exercise participation, answer questions, set new goals, and provide further information on possible lifestyle adjustments to promote active lifestyle. An activity monitor (FitBit Zip, FitBit, San Francisco, CA) was given to participants to provide feedback information of their activity. A custom questionnaire was used to measure each participants experience with the health coach. Participants were asked to rank their overall experience with the health coach (very positive, somewhat positive, neither positive or negative, somewhat negative, very negative), the likelihood of meeting with a health coach at the end of the study, and whether they would recommend others to meet with a health coach (very true, mostly true, somewhat true, not true at all).

## DATA ANALYSIS

For the two cases, changes for each outcome were described as a percentage increase or decrease between: 1) baseline testing (just prior to exercise intervention) and the end of the intervention; and 2) end of the intervention and third month follow-up (12 months after THA).

The parent longitudinal study group was stratified by sex to allow comparison between cases. Relative and percentage difference scores were calculated between the two participants in the case series and averages from the historical cohort 12 months after THA for HOS score, performance of TUG, SCT, and 6MW, and quadriceps and hip abductors strength from the surgical side. Pre-operative demographic characteristics of the two cases and the historical sample are reported in Table 2.

## OUTCOMES

### Feasibility analysis

Both patients completed all exercise sessions. The exercise logs for the first, ninth, and eighteenth sessions are given in appendix A (case A) and appendix B (case B) as a representation of the content and progression of exercises. Case A reported one episode of severe hip pain on the operated side that developed after the eighth exercise session (Appendix C). However, the patient did not report hip pain immediately prior to or after the ninth session. Case A reported low back pain at the beginning of most exercise sessions; however, the pain decreased or did not change at the end of each session. Case B reported low-level pain in the surgical hip after the first two exercise sessions, but this pain did not persist (Appendix D).

## INTERVENTION EFFECT

### Case A

Compared to baseline, there was a 14% improvement of HOS score by the end of the intervention, which was maintained 12 months after THA (Table 3). Hip abductor and quadriceps strength on the operated side increased approximately 30% from baseline and quadriceps strength was symmetrical between legs (symmetry index [surgical/non-surgical] = 0.96). Between the end of the intervention and between the end of the intervention and the twelfth month after THA, hip and knee strength increase 28 and 13%, respectively. Despite the improvement in strength and HOS, there were no substantial changes in performance-based measures of function (TUG, SCT, and 6MW).

At the end of the intervention, the FSS score improved 22% compared to baseline. The I-PAQ score increased to 12558 MET/week from 2838

**Table 2.** Preoperative characteristics of the two participants recruited for the current study compared with the female and male participants of the parent longitudinal study

	Parent longitudinal study		Parent longitudinal study	
	Case A	AVG (SD) N = 16	Case B	AVG (SD) N = 16
Gender	Female	Female	Male	Male
Age, years	61	63 (8)	61	65 (7)
Height, m	1.55	1.66 (0.07)	1.86	1.79 (0.06)
Weight, kg	55	77.66 (17.91)	109	96.02 (21.50)
BMI, kg*m2	22.89	28.06 (5.66)	31.51	29.66 (5.52)
HOS, %	39.47	62.40 (17.89)	71.05	57.46 (15.38)
Hip SX, [0-10]	7	4.9 (2.8)	3	5.5 (1.5)
Knee SX, [0-10]	8	1.8 (2.5)	1	2.5 (2.5)
Hip NSX, [0-10]	0	0.3 (0.7)	0	0.2 (0.4)
Knee NSX, [0-10]	0	0.7 (1.8)	0	0.5 (1.5)
Low Back, [0-10]	0	1.3 (1.7)	0	2.5 (2.2)
TUG, s	6.11	9.67 (2.92)	5.11	8.72 (1.99)
SCT, s	12.3	17.78 (8.06)	9.11	15.81 (5.50)
6MW, m	435.2	447.30 (108.90)	523.69	456.28 (90.68)
Hip strength SX, N/Kg	1.57	1.47 (0.69)	1.08	1.28 (0.78)
Hip strength NSX, N/Kg	1.57	2.06 (0.69)	2.45	1.77 (0.78)
Knee strength SX, N/Kg	4.63	6.62 (2.12)	7.86	5.38 (2.81)
Knee strength NSX, N/Kg	5.65	8.24 (3.05)	8.63	7.30 (3.59)
Abbreviation: AVG= average; SD= standard deviation; BMI= body mass index; HOS= hip outcome survey; SX= surgical; NSX= non-surgical; TUG= timed up and go; SCT= stair climbing time; 6MW= six minute walk				

MET/week at baseline and the PSFS reached a score of 10 (maximum score) for all activities. These results were maintained 12 months after THA. Symmetry index for vertical ground reaction force increased 14% at the end of the intervention (Figure 2).

Before THA, Case A had lower score on the HOS, worse performance in the 6MW, and lower hip adductor and quadriceps strength compared to the average female patients in the longitudinal parent study (Table 2). When these outcomes were evaluated at the 12-month follow-up, she outperformed the average female patients in the longitudinal parent study (Table 4). Case A rated her overall experience with the health coach as “somewhat positive”, but reported that she would not continue to meet with a health coach after the study.

#### Case B

At the end of the intervention, there were no improvements in HOS score and performance-based

tests of function, but hip abductor and knee strength on the operated side improved 22 and 31%, respectively. Despite the improvement during the course of the exercise intervention, hip and knee strength decreased 27% and 8% by the 12 months after THA follow up compared to the end of the intervention. There were no substantial changes in performance-based measures of function (TUG, SCT, and 6MW) during the intervention time frame.

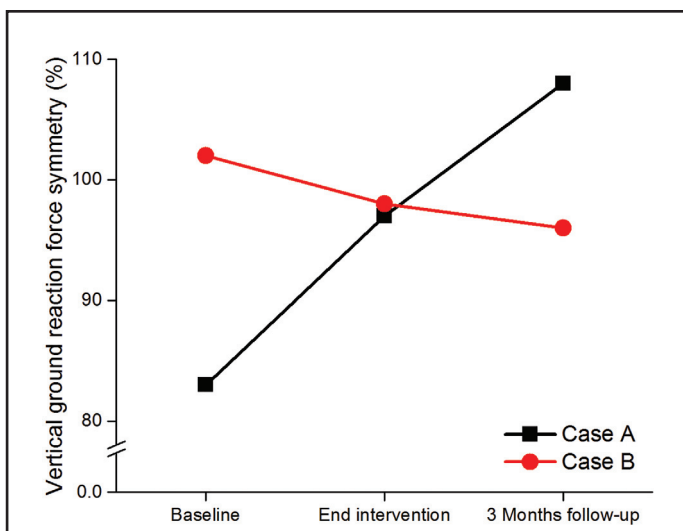
The FSS score improved 47% compared to baseline, and he had substantial improvements in the I-PAQ, which increased to 4759.5 MET/week from 891 MET/week. The participant reported improvement in the PSFS, which reached a level of 9 for golfing and 7 for running. Improvements in the FSS, I-PAQ, and PSFS were maintained 12 months after THA.

Case B had better performance in the TUG, SCT, and 6MW tests compared to average male scores (Table 4) both before and 12 months after THA. Despite

**Table 3.** Patient-reported outcome, impairment-based, and performance-based measures for Case A and Case B assessed before and after the intervention, and at the third-month follow-up. Percentage change between the time points is also calculated

	Case A					Case B				
	Baseline	End intervention	12-month post THA	Percentage change		Baseline	End intervention	12-month post THA	Percentage change	
				Baseline - End intervention	End intervention - 12-month post THA				Baseline - End intervention	End intervention - 12-month post THA
Weight, Kg	55	54	55	-2	2	108	103	106	-5	3
BMI, kg*m2	22.89	22.47	22.89	-2	2	31.49	29.77	30.63	-5	3
SX hip pain, VAS [0-10]	1	1	1	0	0	0	0	0	0	0
SX knee pain, VAS [0-10]	0	1	2	NA	100	2	0	1	-100	
NSX hip pain, VAS [0-10]	0	0	0	0	0	0	0	0	0	0
NSX knee pain, VAS [0-10]	0	0	0	0	0	2	0	1	-100	NA
Low Back pain, VAS [0-10]	5	2	6	-60	200	2	0	0	-100	NA
HOS, %	87.5	100	99	14	-1	97.36	100	98	3	-2
TUG, s	4.94	4.96	5.04	0	2	4.43	4.43	4.43	0	0
SCT, s	9.82	8.92	9.28	-9	4	7.63	7.47	7.56	-2	1
6MW, m	636.42	664.6	669	4	1	688.23	690.8	736	0	7
SX hip strength, N/Kg	1.37	1.76	2.26	29	28	0.88	1.08	0.78	22	-27
NSX hip strength, N/Kg	2.25	2.64	3.04	17	15	2.55	2.45	2.75	-4	12
SX knee strength, N/Kg	6.8	9.25	10.45	36	13	6.98	9.13	8.4	31	-8
NSX knee strength, N/Kg	7.83	9.61	10.7	23	11	8.54	7.22	10.64	-15	47
I-PAQ, MET/week	2838	12558	13750	342	9	891	4759.5	5814	434	22
FFS, [0-63]	32	25	24	-22	-4	43	23	25	-47	9
PSFS, [0-10]										
Walking long distances	7	10	10	43	0					
Walking upstairs	5	10	10	100	0				NA	
Hiking uphill	4	10	10	150	0					
Fast walking	5	10	10	100	0					
Golf				NA		6	9	9	50	0
Running						4	7	7	75	0

BMI= body mass index; HOS= hip outcome survey; SX= surgical; NSX= non-surgical; VAS= verbal analog scale; TUG= timed up and go; SCT= stair climbing time; 6MW= six minute walk; I-PAQ= International physical activity questionnaire (short form); FFS= fatigue severity scale; PSFS= patients specific functional scale.



**Figure 2.** Vertical ground reaction force symmetry index for Case A (black line and squares) and Case B (red line and circles) at baseline, end intervention and 3-months follow-up evaluation timepoints. Symmetry index is calculated by dividing the value of the operated leg with the value of the non-operated leg, and 100% represent perfect symmetry.

better performance on these tests, his quadriceps and hip abductor strength were lower compared to the average male participant. Case B presented with symmetrical ground reaction force at baseline and no changes were measured after the intervention (Figure 2). Case B rated his experience with the health coach as “very positive” and would be likely to recommend that others meet with a health coach.

## DISCUSSION

Reductions in joint pain and high satisfaction rates after THA often overshadow the persistent post-surgical impairments, such as muscle weakness and reduced levels of physical activity. Although these may be considered incidental impairments, they can have a substantial impact on patients' quality of life, particularly in young and active patients. The results of this case series suggest that impairments, such as weakness and reduced physical activity, can be improved with targeted interventions, even late in

**Table 4.** Patient reported outcome, performance-based, and strength measure of the two participants recruited for the current study and the female (N = 16) and male (N = 16) participants of the parent longitudinal study at the 12-month follow up visit

	Case A	Parent longitudinal study [female N = 16]	Relative difference [case A - longitudinal]	Percentage difference
HOS, %	94.40	91.04	3.36	3.62
TUG, s	5.05	7.22	-2.17	-35.37
SCT, s	9.29	12.90	-3.62	-32.59
6MW, m	669.00	538.30	130.70	21.65
Knee strength SX, N/Kg	10.45	6.71	3.74	43.59
Hip strength SX, N/Kg	2.26	1.27	1.01	55.56
	Case B	Parent longitudinal study [male N = 16]	Relative difference [case B - longitudinal]	Percentage difference
HOS, %	98.70	95.40	3.30	3.40
TUG, s	4.43	6.95	-2.52	-44.29
SCT, s	7.56	10.28	-2.72	-30.49
6MW, m	736.00	592.20	143.80	21.65
Knee strength SX, N/Kg	8.40	9.74	-1.34	-14.77
Hip strength SX, % N/Kg	0.78	1.76	-0.98	-76.92
Abbreviation: HOS= hip outcome survey; SX= surgical; NSX=non-surgical; TUG= timed up and go; SCT= stair climbing time; 6MW,=six minute walk				

the recovery phase. The intervention was feasible in a clinical setting and showed an increased strength and functional abilities in two subjects without prolonged exacerbation of symptoms. Pain in the surgical hip at the end of a session was reported a total of three times, was limited to minimal pain, and may have been related to the beginning of an exercise routine or higher level of exercises. Assessing pain and potential exercise adverse effects may help clinician tailoring session that promote gains, while limiting patients' discomfort.<sup>32</sup>

At the end of the intervention, muscle strength on the operated side improved on average 25% for the hip abductors and 33% for the knee extensor. Case A strength exceeded pre-operative values for both the hip abductor and quadriceps muscles. Case A demonstrated symmetrical quadriceps strength, which was maintained 12 months after THA. When compared to female subjects in the longitudinal study, Case A had 53 and 43% greater hip abductor and quadriceps strength 12-months post THA. Case B demonstrated strength gains during the intervention, but was not able to achieve pre-operative levels and strength decreased at the 3-month follow-up. Compared to male subjects in the longitudinal

study, Case B had 76% and 14% weaker hip abductor and quadriceps strength 12-months post THA. It is possible that strength gains in this individual were limited by tissue damage associated with the anterolateral surgical approach,<sup>34</sup> or intraoperative considerations like insufficient femoral offset.<sup>35</sup> In retrospect, Case B may have benefited from a longer duration program or continuation with an independent regimen after discharge from the intervention. However, currently there are no prognostics indicators to identify participants who will benefit from longer care or independent exercise regimens.

Both cases demonstrated changes in the PSFS that exceeded the minimal detectable change.<sup>28</sup> Using exercises that target patient-specific goals may improve patient engagement, provide changes that are meaningful to the patient, and foster changes in overall physical activity. Although both individuals in this case series performed well on the common performance measures, they reported low levels of physical activity compared to previously reported data in patients after THA (approximately 3000met/week).<sup>36</sup> Both individuals demonstrated large improvements in self-reported activity levels at the end of the intervention, which were

also maintained after discharge. The change of the I-PAQ questionnaire exceeded the minimal detectable change for individuals following knee or hip arthroplasty (MDC: 1039 MET/week).<sup>36</sup> Paired with decreased fatigue, these changes may indicate that the intervention improved cardiovascular fitness and endurance. Anecdotally, both individuals reported more confidence with physical exercises. These results may suggest that the intervention promoted the resumption of a more active lifestyle, which may promote weight loss in patients that are overweight: at the end of the intervention case B experienced a clinically meaningful reduction of body weight,<sup>37</sup> although this change was not maintained three months after discharge from the intervention.

The two cases may have had different experiences in relation to the health coach. When asked to elaborate regarding her experience, Case A reported setting goals for herself and healthy eating were already part of her daily routine, and that she did not need external assistance. It should be noted that her body weight and BMI were lower than the average in the historical cohort. Based on these answers, not all patients may benefit from this type of behavioral intervention. Identifying those who may benefit from this service may help optimize outcomes without overusing resources.

## CONSIDERATION FOR FUTURE INTERVENTIONS

The proper “dosage” of supervised sessions should be assessed to maximize the benefits-cost ratio, especially in relation to the current healthcare market. Reducing the number of supervised sessions may reduce the cost associated with the intervention or increase the duration of the intervention, without altering outcomes. The ability of the behavioral intervention to optimize outcomes related to activity level and participation, independent of a physical intervention, should also be evaluated in future studies. The intervention constructs used here could be also tailored to a traditional post-THA rehabilitation approach. Once soft-tissue and post-operative restrictions are removed, patients could participate in a progressive program to address cardiovascular fitness, muscle strength and physical activity.

## LIMITATIONS

The absence of a direct measure of physical activity (i.e., using an activity monitor) is considered a limitation of this study because patients post-arthroplasty tend to overestimate their self-reported activity level.<sup>12</sup> Inherent limitation of this type of case-series include the lack of generalizability of the results, although the comparison with an historical cohort gives an interesting perspective on the changes promoted by the intervention.

## CONCLUSION

The exercise intervention protocol used in this case series improved leg strength, weekly physical activity, and the ability to perform demanding recreational and sport participation, without producing adverse effects. These improvements occurred even though patients in this case series scored well on common performance tests, such as TUG, SCT, and 6MW. This intervention is a novel approach that could potentially increase activity levels and restore recreational participation in patients after THA.

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## Appendix A. Exercise Log for Sessions One, Nine and Eighteen for Case A

Session # 1				
	Mode	Distance (m)	Parameters	
Aerobic Session 1	Bike	4570	Resistance: 5 cadence > 60	
Aerobic Session 2	Elliptical	1432	Resistance: 1 crossramp: 1	
	Exercise	Sets	Repetition	Resistance
Strengthening	Leg press	2	10	10kg
	Bridge with abductor rubber band	2	10	green band
	Sideling hip abductor	2	10	green band
	Leg extension (full range)	2	10	green band
Session # 9				
	Mode	Distance (m)	Parameters	
Aerobic Session 1	Bike	4570	Resistance: 7; cadence > 60	
Aerobic Session 2	Elliptical	1609	Resistance: 3; crossramp: 7	
	Exercise	Sets	Repetition	Resistance
Strengthening	Leg press	3	10	20kg
	Abductor rise	3	10	1.5kg
	Single leg step down	3	10	16 cm block; holding 1kg ball
Session # 18				
	Mode	Distance (m)	Parameters	
Aerobic Session 1	Bike	5648	Resistance:6 cadence > 80	
Aerobic Session 2	Elliptical	1657	Resistance: 1 crossramp: 1	
	Exercise	Sets	Repetition	Resistance
Strengthening	Single leg bridge	3	10	20kg
	Single leg stance	8	10	Multidirectional balance board; 10 ball tosses per set
	Single leg step up	3	10	16 cm block with foam pad on top
	Leg curls (prone)	3	10	5kg

## Appendix B. Exercise Log for Sessions One, Nine and Eighteen for Case B

Session # 1				
	Mode	Distance (m)	Parameters	
Aerobic Session 1	Treadmill	981	Speed: 4.02 km/h; incline: 7.5%	
Aerobic Session 2	Bike	4618	Resistance 5 cadence > 70	
	Exercise	Sets	Repetition	Resistance
Strengthening	Bridge with abduction rubber band	3	10	red band
	Sideling hip abductor	2	10	2.5kg
	Leg extension (full range)	3	10	30kg
	Sit ups	3	10	foam pad
Session # 9				
	Mode	Distance (m)	Parameters	
Aerobic Session 1	Bike	5777	Resistance: 7 cadence > 80	
Aerobic Session 2	Treadmill	1126	Speed: 4.67 km/h; incline: 7.5%	
	Exercise	Sets	Repetition	Resistance
Strengthening	Leg extension (full range)	3	10	50kg
	Leg curl (full range)	3	10	40kg
	Hip extension (prone)	3	10	1.5kg, hold for 5 sec
Session # 18				
	Mode	Distance (m)	Parameters	
Aerobic Session 1	Treadmill	1335	Speed: 5.47 km/h; incline: 6.5%	
Aerobic Session 2	Bike	5841	Resistance: 5 cadence > 90	
	Exercise	Sets	Repetition	Resistance
Strengthening	Golf swing	2	10	Holding 5kg ball
		2	10	Holding 3kg ball, higher speed
	Trunk rotation on exercise ball	2	10	Holding 5kg ball
		2	10	Holding 3kg ball, higher speed
	Golf swing	3	5	Different balance boards and BOSU
	Golf put	3	5	Different balance boards and BOSU

**Appendix c.** *Appendix C. Case A self-reported severe joint pain, swelling, tenderness, developed the day after each exercise session; and verbal analog scale (VAS) for pain before and after each exercise session*

Case	Session	Symptoms the day after the exercise session			Before exercise session					After exercise session				
		Severe joint pain	Joint swelling	Joint tenderness	Pain, VAS [0-10]					Pain, VAS [0-10]				
					Hip SX	Knee SX	Hip NSX	Knee NSX	Low Back	Hip SX	Knee SX	Hip NSX	Knee NSX	Low Back
A	#1		NA		0	0	0	0	3	0	0	0	0	0
	#2	No	No	No	0	0	0	0	3	0	0	0	0	0
	#3	No	No	No	0	0	0	0	3	0	0	0	0	1
	#4	No	No	No	0	0	0	0	2	0	0	0	0	1
	#5	No	No	No	0	0	0	0	1	0	0	0	0	1
	#6	No	No	No	0	0	0	0	2	0	0	0	0	1
	#7	No	No	No	0	0	0	0	2	0	0	0	0	0
	#8	Yes <sup>a</sup>	No	No	0	0	0	0	1	0	0	0	0	0
	#9	No	No	No	0	0	0	0	1	0	0	0	0	1
	#10	No	No	No	0	0	0	0	0	0	0	0	0	1 <sup>b</sup>
	#11	No	No	No	0	2	0	0	0	0	0	0	0	1 <sup>b</sup>
	#12	No	No	No	0	0	0	0	0	0	0	0	0	0
	#13	No	No	No	0	0	0	0	0	0	0	0	0	0
	#14	No	No	No	0	0	0	0	2	0	0	0	0	0
	#15	No	No	No	0	0	0	0	2	0	0	0	0	0
	#16	No	No	No	0	2	0	0	2	0	0	0	0	0
	#17	No	No	No	0	1	0	0	2	1 <sup>b</sup>	1	0	0	1
	#18	No	No	No	1	1	0	0	2	0	0	0	0	1

<sup>a</sup>, Episode of groin pain that lasted for a few minutes.

<sup>b</sup>, Pain developed during the exercise intervention.

SX= surgical; NSX= non-surgical.

**Appendix D.** *Case B self-reported severe joint pain, swelling, tenderness, developed the day after each exercise session; and verbal analog scale (VAS) for pain before and after each exercise session*

Case	Session	Symptoms the day after the exercise session			Before exercise session					After exercise session				
		Severe joint pain	Joint swelling	Joint tenderness	Pain, VAS [0-10]					Pain, VAS [0-10]				
					Hip SX	Knee SX	Hip NSX	Knee NSX	Low Back	Hip SX	Knee SX	Hip NSX	Knee NSX	Low Back
B	#1		NA		0	0	0	0	0	1 <sup>a</sup>	0	0	0	0
	#2	No	No	No	0	0	0	0	0	2 <sup>a</sup>	0	0	0	0
	#3	No	No	No	0	0	0	0	0	0	0	0	0	0
	#4	No	No	No	0	0	0	0	0	0	0	0	0	0
	#5	No	No	No	0	0	0	0	0	0	0	0	0	0
	#6	No	No	No	0	0	0	0	0	0	0	0	0	0
	#7	No	No	No	0	0	0	0	0	0	0	0	0	0
	#8	No	No	No	0	0	0	0	0	0	0	0	0	0
	#9	No	No	No	0	0	0	0	0	0	0	0	0	0
	#10	No	No	No	0	0	0	0	0	0	0	0	0	0
	#11	No	No	No	0	0	0	0	0	0	0	0	0	0
	#12	No	No	No	0	0	0	0	0	0	0	0	0	0
	#13	No	No	No	0	0	0	0	0	0	0	0	0	0
	#14	No	No	No	0	0	0	0	0	0	0	0	0	0
	#15	No	No	No	0	0	0	0	0	0	0	0	0	0
	#16	No	No	No	0	0	0	0	0	0	0	0	0	0
	#17	No	No	No	0	0	0	0	0	0	0	0	0	0
	#18	No	No	No	0	0	0	0	0	0	0	0	0	0

<sup>a</sup>, Pain developed during the exercise intervention.

SX= surgical; NSX= non-surgical